Appendix: Roadmap Objectives

Astrobiology and the roadmap

Astrobiology is the study of the origins, evolution, distribution, and future of life in the universe. It requires fundamental concepts of life and habitable environments that will help us to recognize biospheres that might be quite different from our own. Astrobiology embraces the search for potentially inhabited planets beyond our Solar System, the exploration of Mars and the outer planets, laboratory and field investigations of the origins and early evolution of life, and studies of the potential of life to adapt to future challenges, both on Earth and in space. Interdisciplinary research is needed that combines molecular biology, ecology, planetary science, astronomy, information science, space exploration technologies, and related disciplines. The broad interdisciplinary character of astrobiology compels us to strive for the most comprehensive and inclusive understanding of biological, planetary and cosmic phenomena.

This NASA Astrobiology Roadmap outlines these multiple pathways for research and exploration and indicates how they might be prioritized and coordinated. The roadmap embodies the efforts of more than 200 scientists and technologists, including NASA employees, academic scientists whose research is partially funded by NASA grants, and many members of the broader community who have no formal association with NASA.

Fundamental Questions

Astrobiology addresses three basic questions, which have been asked in some form for generations. Astrobiology is exciting today because we have the technology to begin to answer them.

- How does life begin and evolve?
- Does life exist elsewhere in the universe?
- What is the future of life on Earth and beyond?

Principles

This roadmap emphasizes the following four principles that are fundamental to the operation of the Astrobiology Program:

- Astrobiology is multidisciplinary in its content and interdisciplinary in its execution. Its success depends critically upon the close coordination of

diverse scientific disciplines and programs, including space missions.

- Astrobiology encourages planetary stewardship through an emphasis on protection against forward and back biological contamination and recognition of ethical issues associated with exploration.
- Astrobiology recognizes a broad societal interest in its endeavors, especially in areas such as achieving a deeper understanding of life, searching for extraterrestrial biospheres, assessing the societal implications of discovering other examples of life, and envisioning the future of life on Earth and in space.
- The intrinsic public interest in astrobiology offers a crucial opportunity to educate and inspire the next generation of scientists, technologists and informed citizens; thus a strong emphasis upon education and public outreach is essential.

Roadmap Objectives

Objective No. 1.1:	Models of formation and evolution of habitable planets
Objective No. 1.2:	Indirect and direct astronomical observations of extrasolar habitable planets
Objective No. 2.1:	Mars exploration
Objective No. 2.2:	Outer Solar System exploration
Objective No. 3.1:	Sources of prebiotic materials and catalysts
Objective No. 3.2:	Origins and evolution of functional biomolecules
Objective No. 3.3:	Origins of energy transduction
Objective No. 3.4:	Origins of cellularity and protobiological systems
Objective No. 4.1:	Earth's early biosphere
Objective No. 4.2:	Foundations of complex life
Objective No. 4.3:	Effects of extraterrestrial events upon the biosphere
Objective No. 5.1:	Environment–dependent, molecular evolution in microorganisms
Objective No. 5.2:	Co–evolution of microbial communities
Objective No. 5.3:	Biochemical adaptation to extreme environments
Objective No. 6.1:	Environmental changes and the cycling of elements by the biota, communities, and ecosystems
Objective No. 6.2:	Adaptation and evolution of life beyond Earth
Objective No. 7.1:	Biosignatures to be sought in Solar System materials
Objective No. 7.2:	Biosignatures to be sought in nearby planetary systems